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9.0 GENERAL

State of Wisconsin Standard Specifications for Road and Bridge Construction contains the physical requirements designating the AASHTO or ASTM conforming specifications for the materials used in bridge construction. This chapter gives an explanation of material applications and their properties.

In cases where proprietary products are experimentally specified, special provisions are written setting forth material properties and installation procedures. Manufacturer's recommendations for materials and their assistance during installation may be specified.

Materials that are proposed for incorporation into highway construction work performed under the jurisdiction of the Wisconsin Department of Transportation may be approved or accepted by a variety of procedures:

1. Laboratory materials testing of submitted or randomly selected samples.
2. Inspection and/or tests at the source of fabrication or manufacture.
3. Inspection and/or testing in the field by highway personnel.
4. Manufacturer's certificate of compliance and/or manufacturer's certified report of test or analysis, either as sole documentation for acceptance or as supplemental documentation.
5. Inspection, evaluation and testing in the normal course of project administration of materials specifications.

The Construction and Materials Manual contains a full description of procedures for material testing and the procedures required for each material.

9.1 CONCRETE

| Bridge decks on stringers and concrete slab bridges are designed using a concrete ultimate strength of 4000 psi (28 MPa). This value is substantiated by evaluation of cylinder tests on concrete decks placed in the field which show almost all strengths equal or exceed this concrete strength which is designated as Class D.

All other concrete structural members except prestressed are designed by using an ultimate strength of 3500 psi (24 MPa). There is less cement in this concrete. This concrete is designated as Grade A.

Allowable concrete stresses for prestressed structural members and prestressed concrete piles are given in the Chapters covering these subjects along with the design methods. The concrete is designated as Grade C. Grade “E” concrete is specified for Low Slump Concrete deck and slab overlays.

9.2 REINFORCEMENT BARS

Reinforced concrete structures are designed for Grade 60 (Grade 420) bar steel with a yield strength of 60 ksi (420 MPa).

Epoxy coated Grade 60 bar steel shall be used for both top and bottom layer slab steel on all new or redecked State highway bridges and for all local bridges. All curbs, parapets, median, sidewalk, abutment wingwall parapet, abutment paving notch, abutment backwalls including the vertical steel through the construction joint, shall be epoxy coated. Epoxy coated bar steel shall be used on all piers detailed with expansion joints and on median piers at grade separations where the ADT under the bridge is greater than 3500. Use epoxy coated bars down to the top of footing elevation.

Welding of bar steel is not permitted unless approved by the Engineer or used in an approved butt splice. Test results show that the fatigue strength of bars is reduced if stirrups are tack welded to the bars. A contractor may want to support a deck joint by welding attachments to the bar steel which is not permitted. The bar steel mat does not provide adequate stability to support deck joints or similar details during the slab pour to maintain the correct elevations.

Bridge plans show the quantities of bar steel required. Details are not shown for bar chairs or other accessories necessary to place the bar steel. This information is covered by the Construction Specifications and is part of the bid quantity.

When determining the anchorage requirements for bars, consider the bar size as well as using hooks. Note in the tables that smaller bars require considerably less anchorage length than larger bars and the development length is less if the bar spacing is 6 inches (150 mm) or more. By detailing smaller bars to get the required area spaced 6 inches (150 mm) or more apart, less steel is used. Bar hooks may reduce the required bar development lengths; however, the hooks may cost more to fabricate. Although in cases such as footings for columns or retaining walls; hooks may be the only practical solution because of the concrete depth available.

Fabricators stock all bar sizes in 60 foot (18 m) lengths. For ease of handling, the detailed length of No. 3 & 4 bars are limited to 45 feet. Longer bars may be used at the discretion of the Engineer where larger quantities are needed so that more assistance is available for handling the longer bars. All other bar sizes are detailed to a maximum length except for vertical bars. Bars placed in a vertical position are limited to lengths of 30 feet (9 m). The location of mandatory horizontal construction joints in pier shafts or columns will generally determine the length of vertical bars in piers. All bars are detailed to the nearest one inch.

In stress zones the maximum allowable change in bar size is three bar sizes. If bars are bundled, the individual bar ends are terminated at least 40 bar diameters apart.

A. Development Length of Bars

Tables are available giving the development length of bars according to AASHTO Specifications and the allowable design stresses by Wisconsin DOT.

Table 9.1 gives the required lap length of spliced tension bars for allowable stresses of: f'c = 3500 psi (24 MPa) and fy = 60 ksi (420 MPa). These values are used for all reinforced concrete except deck slabs. Table 9.2 provides information for deck slabs.

The lap length for stirrups and tie bars according to AASHTO is 1.7 ld. Our interpretation of the lap length for temperature and distribution bar steel is a Class A splice (either top or others).

AASHTO Specifications allow compression bars to terminate in bearing on top of the footing. A minimum amount of dowel bar steel is required for compression bars to assure structural integrity; however, this is provided if tension bars are developed.

The minimum embedment distance for hooked bars is arbitrarily chosen as 8 inches (200 mm) for adequate embedment of the hook. This distance increases with the bar size, as more development length is needed. The basic development length for a hooked bar (1_{hb}) is a function of bar diameter (d_b) and concrete strength (f'c). Development length (1_{hb}) shall be multiplied by applicable modification factors to produce required development length (1_{dh}).

Embedment distance is increased for dowel bars if the hook does not rest on top of the bar steel mat in the bottom of the footing. This is a construction detail which is the best way to anchor the bars before the concrete is placed.

Dowel bars are used in footings as tensile members. Bar steel is saved by varying the dowel bar lengths in order that only half the bars are spliced in the same plane. This is a consideration for long retaining walls and in some columns. This gives a Class B splice as otherwise for equal length dowel bars, all splices are Class C.

B. Bends and Hooks

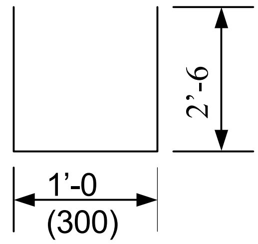
Tables 9.5 and 9.6 show the minimum dimensions for hooks and bends of bars and stirrups as computed from the AASHTO Specifications. Dimensions in the bending details are given out to out. In computing total bar lengths account for the accumulation in length in the bends. One leg of bent bars is not dimensioned so that the error tolerance in length caused by bending can be placed in this leg. The Concrete Reinforcing Steel Institute (CRSI) Manual of Standard Practices provides standard bending tolerances that are permitted.

Where the lengths are not shown, minimum development lengths are required for hooks as specified in the Wisconsin Standard Construction Specifications.

Example 1 shows typical detailing procedures for bars with bends.

Example 1.

No. 25 Bar



Bar length = 1.0 + (2)2.5 - (2) .21 = 5.58 or 5'-7 to the nearest inch.

(Bar length = 300 + (2)750 - (2) 60 = 1680 mm or 1700 mm to the nearest 50 mm).

C. Bill of Bars

Table 9.7 shows a sample bill of bars for a concrete slab. Different bar letter designations are used for abutments, slabs, and culverts, etc. The column for bundled bars is omitted if they are not used. A column for bar series is added if bars are cut. If epoxy coated bars are used, samples will be randomly selected for testing.

D. Bar Series

Bar Series enable the detailer to detail bar steel in the simplest manner if they are used properly. Also, it helps the fabricator to prepare the bill of bars.

The following general rules apply to Bar Series:

1. Equal spacing of bars is required.
2. There may be more than 1 Series with same number of bars.
3. The total length of a bar is 60 feet (18 m) maximum.
4. The minimum number of bars per Series is 4.
5. Bent bars are bent after cutting.
6. Set numbers are assigned to each Series used.

Table 9.8 provides a sample layout for a bar series. The bar table will show the number of bars and the average length.

9.3 STEEL

Structural steel is used in bridge construction for steel girders, trusses, certain bearings and expansion joints, piling and special long bridges. The chapter covering a specific subject explains where the various grades of steel are used. AASHTO Specifications give the necessary design information for each grade of steel including allowable design stresses.

Chapter 45 - Bridge Rating documents the history of steel and allowable material stresses used in previous years for bridge designs.

More attention is being focused on the ability of bridge steels to withstand fracture. Cracks occur in bridge steels due to fabrication, fatigue and stress corrosion. For a structure to be safe from failure due to these small cracks they must have a certain plane-strain fracture toughness. This value is determined using the Charpy V-notch tests. The tests are required on all steels used for structural girders. The construction specifications give the required test values for each grade of steel.

9.4 MISCELLANEOUS METALS

Wisconsin Standard Construction Specifications give the requirements for most other metals used in bridge construction. Some metals and new materials are specified by special provisions. Following is a list of some of these metals and their applications.

| Zinc Plate is used as a separator for concrete joints. Plastic may also be used.

| Aluminum is used for sign bridges and certain railings.

Sheet Copper may be used as a waterstop for railroad bridges or as flashing on movable bridge operator buildings. Recent cost increases have reduced the usage of sheet copper.

Lubricated Bronze Plates or Stainless Steel Plates or Sheets are used on expansion bearings.

Cast Gray Iron conforming to ASTM A48, Class 30, or galvanized steel is used for floor drains and downspouts. Downspouts may also be Fiberglass as shown on the Standards.

Low relaxation strands are used for prestressing concrete. Prestressing reinforcement is seven wire strands woven to 0.5 or 0.6 inch nominal diameter.

A special casting of copper, lead, zinc and tin is used for bridge name plates.

9.5 TIMBER

Timber is used primarily for timber structures, piling, and falsework. Allowable stresses and loads are given in the appropriate chapters in the manual.

9.6 MISCELLANEOUS MATERIALS

Several types of materials are being tried for bridge deck protective systems. Some of these products are experimental and are placed on designated structures. Following is a list of products currently used or under evaluation:

1. Epoxy Coated Reinforcing Bar Steel.
2. Waterproofing Membrane with Bituminous Concrete Overlay.
3. Cathodic Protection Systems with Surface Overlays.
4. Low Slump Concrete Overlays.
5. Protective Surface Treatment on all New Concrete Decks and Slabs.

Preformed Fabric, Class A, is used on bridge seats under structural bearings.

Construction fabrics or geotextiles are used to separate materials or to provide subgrade reinforcement. Geotextiles are light, flexible, strong and rot-resistant. They generally consist of sheets of woven and nonwoven synthetic polymers such as polypropylene, polyester, polyethylene or nylon. Depending on the project size, manufacturers supply geotextiles in rolled sheets of various lengths and widths. Geotextile specifications are given in AASHTO M288. Typical structure related applications are under granular backfill and riprap, for slope stabilization and as drainage ditch liners.

Elastomeric bearing pads are primarily used as bearings for prestressed girders. Steel laminated elastomeric bearing pads are recommended for prestressed girders at expansion pier locations.

Downspouts and collector systems for floor drains may be fabricated from fiberglass conforming to ASTM D2996, Grade I, Class A.

Specifications are given in the State of Wisconsin Standard Specifications for Road and Bridge Construction for several materials used in bridge construction. Some of these materials are: Elastomeric bearing pads, preformed joint fillers, neoprene joint seals, lubricant adhesives and asphalt plank. Stainless steel and teflon used on expansion bearings is described in Chapter 27 - Bearings.

9.6A PAINTING

All highway grade separation structures require the use of painted steel since unpainted steel is subject to chlorides from vehicle salt spray. Additional discussion on Painting is presented in Chapter 24 - Steel Girder Structures. Currently, two paint systems are given in the Wisconsin Standard Specifications. However, only the three coat Epoxy System is specified to meet the requirement of 3.5 pounds per gallon or less volatile organic compounds.

Approved standard colors and paint color numbers for steel girders in accordance with Federal Standard No. 595B as printed are:

White (For Inside of Box Girders)	#27925
Blue (Medium Sky Blue Tone)	#25240
* Brown (Similar to Weathering Steel)	#20059
Gray (Light Gray)	#26293
Green (Medium Tone)	#24260
Reddish-Brown (Red Brick Tone)	#20152
Gray (Dark Gray-DNR Request)	#26132
Black	#27038

* Shop applied color for weathering steel.

All steel bearing parts which are not welded to the girder or do not have a teflon or bronze surface and anchor bolts for both bearings and railings shall be galvanized. In addition to galvanizing the bearings shall also be field or shop painted for painted structures and shop painted for unpainted structures.

All new structural steel is sandblasted including weathering steel, as it is proven that paint systems last longer with better surface preparation. The blast cleaned surface is a very finely pitted surface with pit depths of about 1 1/2 mils.

Corrosion of structural steel occurs if the agents necessary to form a corrosion cell are present. A corrosion cell is similar to a battery in that current flows from the anode to the cathode. As the current flows, corrosion occurs at the anode and materials expand. Water carries the electrical current between the anode and cathode. If there is salt in the water, the current travels much faster and the rate of corrosion is accelerated. Oxygen combines with the materials to help form the anodic corrosion cell.

The prime purpose of painting steel structures is protection of the steel surface. Appearance is a secondary function that is maintained by using compatible top coatings over epoxy and vinyl systems.

Paint applied to the steel acts as a moisture barrier. It prevents the water from contacting the steel; a corrosion cell cannot be formed. When applying a moisture barrier, it is important to get an adhering, uniform thickness as well as an adequate thickness. The film thickness of paint wears with age until it is finally depleted. At this point the steel begins to corrode as moisture is now present in the corrosion cell. If paint is applied too thick, it may crack and/or check due to temperature changes and allow moisture to contact the steel long before the film thickness wears down.

The paint inspector uses a paint gauge to randomly measure the film thickness of the paint according to specifications. Wet film thickness is measured and it is always thicker than the dry film thickness. A vehicle is added to the paint solids so that the solids can be applied to a surface and it evaporates leaving only the solids on the surface. The percent of solids in a gallon of paint gives an estimate of the wet to dry film thickness ratio.

Some paints use a primer coat to give galvanic protection if moisture contacts the steel. For example, if zinc and steel are together the zinc sacrifices to the steel. However, the zinc must be fairly close to the exposed steel area or the steel is not protected. Wide scratches in galvanized metal illustrate the ineffectiveness of the zinc protection on the exposed surface.

Refer to the Maintenance Manual for the criteria on spot painting versus complete painting. The Maintenance Manual also has information on testing the paint systems.

Approved standard colors for concrete with federal numbers are as follows:

Pearl Gray	#26622
Medium Tan	#33446
Gray Green	#30372
Dark Brown	#30140
Dawn Mist (Grayish Brown)	#36424
Lt. Coffee (Creamy Brown)	#33722

Most paints require concrete to be a minimum of 30 days old before application. This should be considered when specifying completion times for contracts.

(fc' = 3500 psi; fy=60 ksi)

BAR SPACING	BAR SIZE		4	5	6	7	8	9	10	11	TYPE
6" OR MORE	CLASS A	TOP*	1-2	1-5	1-9	2-4	3-0	3-10	4-10	5-11	UNCOATED
			1-4	1-9	2-1	2-10	3-7	4-7	5-10	7-1	EPOXY
		OTHERS	1-0	1-0	1-3	1-8	2-2	2-9	3-6	4-3	UNCOATED
			1-2	1-6	1-11	2-6	3-3	4-2	5-3	6-4	EPOXY
	CLASS B	TOP*	1-6	1-10	2-3	3-0	3-11	5-0	6-3	7-9	UNCOATED
			1-9	2-3	2-8	3-7	4-8	6-0	7-6	9-4	EPOXY
		OTHERS	1-1	1-4	1-7	2-2	2-10	3-7	4-6	5-6	UNCOATED
			1-3	2-0	2-5	3-3	4-3	5-4	6-9	8-3	EPOXY
	CLASS C	TOP*	1-11	2-5	2-11	3-11	5-1	6-6	8-2	10-1	UNCOATED
			2-3	2-11	3-6	4-8	6-1	7-10	9-10	12-1	EPOXY
		OTHERS	1-5	1-9	2-1	2-10	3-8	4-8	5-10	7-3	UNCOATED
			1-8	2-8	3-2	4-3	5-6	7-0	8-9	10-11	EPOXY
LESS THAN 6"	CLASS A	TOP*	1-5	1-9	2-2	2-11	3-9	4-9	6-1	7-5	UNCOATED
			1-8	2-1	2-7	3-6	4-6	5-8	7-4	8-11	EPOXY
		OTHERS	1-0	1-3	1-6	2-1	2-8	3-5	4-4	5-4	UNCOATED
			1-2	1-11	2-3	3-2	4-0	5-2	6-6	8-0	EPOXY
	CLASS B	TOP*	1-10	2-4	2-9	3-9	4-10	6-2	7-10	9-8	UNCOATED
			2-2	2-10	3-4	4-6	5-10	7-5	9-5	11-7	EPOXY
		OTHERS	1-4	1-8	2-0	2-8	3-6	4-5	5-7	6-11	UNCOATED
			1-7	2-6	3-0	4-0	5-3	6-8	8-5	10-4	EPOXY
	CLASS C	TOP*	2-5	3-0	3-7	4-11	6-5	8-1	10-3	12-7	UNCOATED
			2-10	3-8	4-4	5-11	7-8	9-8	12-4	15-1	EPOXY
		OTHERS	1-9	2-2	2-7	3-6	4-7	5-9	7-4	9-0	UNCOATED
			2-0	3-3	3-11	5-3	6-11	8-8	11-0	13-6	EPOXY

* More than 12 inches of concrete under a horizontal bar.

CLASS A - Bar stress is less than 50%; Bars spliced are 75% or less.

CLASS B - Bar stress is 50% or greater; Bars spliced are 50% or less or Bar stress is less than 50%; Bars spliced are greater than 75%.

CLASS C - Bar stress is 50% or greater; Bars spliced are greater than 50%.

TABLE 9.1 TENSION LAP SPLICE LENGTH OR DEVELOPMENT LENGTH
APPLIES TO LRD OR LRFD

(f'c= 24 MPa fy= 420 MPa) ALL LAPS ARE IN MILLIMETERS

BAR SPACING	BAR SIZE		13	16	19	22	25	29	32	36	TYPE
150 mm OR GREATER	CLASS A	TOP	350 400	450 550	550 650	700 850	950 1100	1150 1400	1500 1800	1800 2200	UNCOATED EPOXY
		OTHERS	300 350	300 450	400 550	500 750	650 1000	850 1250	1050 1600	1300 1950	UNCOATED EPOXY
	CLASS B	TOP	450 550	550 700	700 800	900 1100	1200 1450	1500 1850	1950 2350	2350 2850	UNCOATED EPOXY
		OTHERS	350 400	400 600	500 750	650 1000	850 1300	1100 1650	1400 2050	1700 2550	UNCOATED EPOXY
	CLASS C	TOP	600 700	750 900	900 1050	1200 1450	1550 1900	2000 2400	2500 3050	3100 3750	UNCOATED EPOXY
		OTHERS	450 500	550 800	650 950	850 1300	1100 1700	1400 2100	1800 2700	2200 3300	UNCOATED EPOXY
LESS THAN 150 mm	CLASS A	TOP	450 500	550 650	650 800	900 1050	1150 1400	1450 1750	1850 2250	2250 2750	UNCOATED EPOXY
		OTHERS	300 350	400 600	450 700	650 950	850 1250	1050 1550	1350 2000	1650 2450	UNCOATED EPOXY
	CLASS B	TOP	550 650	700 850	850 1000	1150 1400	1500 1800	1900 2300	2400 2900	2950 3600	UNCOATED EPOXY
		OTHERS	400 500	500 750	600 900	800 1200	1100 1600	1350 2050	1700 2600	2100 3150	UNCOATED EPOXY
	CLASS C	TOP	750 850	950 1100	1100 1350	1500 1800	1950 2350	2500 3000	3150 3800	3850 4650	UNCOATED EPOXY
		OTHERS	550 600	650 1000	800 1200	1050 1600	1400 2100	1750 2650	2250 3350	2750 4150	UNCOATED EPOXY

Top-more than 300 mm of concrete under a horizontal bar.

CLASS A - Bar stress is 50% or less, Bars spliced are 75% or less

CLASS B - Bar stress is greater than 50%, Bars spliced are 50% or less or Bar stress is 50% or less, Bars spliced are greater than 75%.

CLASS C - Bar stress is greater than 50%, Bars spliced are greater than 50%.

TABLE 9.1 TENSION LAP SPLICE LENGTH OR DEVELOPMENT LENGTH

APPLIES TO LFD OR LRFD

(fc'=4000 psi fy=60 ksi)

BAR SPACING	BAR SIZE		4	5	6	7	8	9	10	11	TYPE
6" OR MORE	CLASS A	TOP*	1-2	1-5	1-9	2-2	2-10	3-7	4-6	5-7	UNCOATED
			1-4	1-9	2-1	2-7	3-5	4-4	5-5	6-8	EPOXY
		OTHERS	1-0	1-0	1-3	1-7	2-0	2-7	3-3	4-0	UNCOATED
			1-2	1-6	1-11	2-5	3-0	3-11	4-11	6-0	EPOXY
	CLASS B	TOP*	1-6	1-10	2-3	2-10	3-8	4-8	5-10	7-3	UNCOATED
			1-9	2-3	2-8	3-5	4-5	5-7	7-0	8-8	EPOXY
		OTHERS	1-1	1-4	1-7	2-0	2-7	3-4	4-2	5-2	UNCOATED
			1-3	2-0	2-5	3-0	3-11	5-0	6-3	7-9	EPOXY
	CLASS C	TOP*	1-11	2-5	2-11	3-8	4-9	6-1	7-8	9-5	UNCOATED
			2-3	2-11	3-6	4-5	5-8	7-4	9-2	11-4	EPOXY
		OTHERS	1-5	1-9	2-1	2-8	3-5	4-4	5-6	6-9	UNCOATED
			1-8	2-8	3-2	4-0	5-2	6-6	8-3	10-2	EPOXY
LESS THAN 6"	CLASS A	TOP*	1-5	1-9	2-2	2-8	3-6	4-6	5-8	7-0	UNCOATED
			1-8	2-1	2-7	3-2	4-3	5-5	6-10	8-5	EPOXY
		OTHERS	1-0	1-3	1-6	1-11	2-6	3-2	4-1	5-0	UNCOATED
			1-2	1-11	2-3	2-11	3-9	4-9	6-2	7-6	EPOXY
	CLASS B	TOP*	1-10	2-4	2-9	3-6	4-7	5-10	7-4	9-0	UNCOATED
			2-2	2-10	3-4	4-3	5-6	7-0	8-10	10-10	EPOXY
		OTHERS	1-4	1-8	2-0	2-6	3-3	4-2	5-3	6-6	UNCOATED
			1-7	2-6	3-0	3-9	4-11	6-3	7-11	9-8	EPOXY
	CLASS C	TOP*	2-5	3-0	3-7	4-7	5-11	7-7	9-7	11-10	UNCOATED
			2-10	3-8	4-4	5-6	7-1	9-1	11-6	14-2	EPOXY
		OTHERS	1-9	2-2	2-7	3-3	4-3	5-5	6-10	8-5	UNCOATED
			2-0	3-3	3-11	4-11	6-5	8-2	10-3	12-8	EPOXY

*More than 12 inches of concrete under a horizontal bar.

CLASS A - Bar stress is less than 50%; Bars spliced are 75% or less.

CLASS B - Bar stress is 50% or greater; Bars spliced are 50% or less or Bar stress is less than 50%; Bars spliced are greater than 75%.

CLASS C - Bar stress is 50% or greater, Bars spliced are greater than 50%.

<u>TABLE 9.2 TENSION LAP SPLICE LENGTH OR DEVELOMENT LENGTH</u>

APPLIES TO LFD OR LRFD

(f'c= 28 MPa fy= 420 MPa) ALL LAPS ARE IN MILLIMETERS

BAR SPACING	BAR SIZE		13	16	19	22	25	29	32	36	TYPE
150 mm OR GREATER	CLASS A	TOP	350	450	550	650	850	1100	1350	1700	UNCOATED
			400	550	650	800	1050	1300	1650	2050	EPOXY
		OTHERS	300	300	400	500	600	800	1000	1200	UNCOATED
			350	450	550	700	900	1150	1500	1800	EPOXY
	CLASS B	TOP	450	550	700	850	1100	1400	1800	2200	UNCOATED
			550	700	800	1050	1350	1700	2150	2650	EPOXY
		OTHERS	350	400	500	600	800	1000	1300	1550	UNCOATED
			400	600	750	900	1200	1500	1900	2350	EPOXY
	CLASS C	TOP	600	750	900	1100	1450	1850	2350	2850	UNCOATED
			700	900	1050	1350	1750	2250	2800	3450	EPOXY
		OTHERS	450	550	650	800	1050	1300	1650	2050	UNCOATED
			500	800	950	1200	1550	1950	2500	3050	EPOXY
LESS THAN 150 mm	CLASS A	TOP	450	550	650	800	1050	1350	1700	2100	UNCOATED
			500	650	800	1000	1300	1650	2100	2550	EPOXY
		OTHERS	300	400	450	600	750	950	1250	1500	UNCOATED
			350	600	700	900	1150	1450	1850	2250	EPOXY
	CLASS B	TOP	550	700	850	1050	1400	1750	2250	2750	UNCOATED
			650	850	1000	1300	1700	2150	2700	3300	EPOXY
		OTHERS	400	500	600	750	1000	1250	1600	1950	UNCOATED
			500	750	900	1150	1500	1900	2400	2950	EPOXY
	CLASS C	TOP	750	950	1100	1400	1800	2300	2900	3600	UNCOATED
			850	1100	1350	1650	2200	2800	3550	4350	EPOXY
		OTHERS	550	650	800	1000	1300	1650	2100	2550	UNCOATED
			600	1000	1200	1500	1950	2450	3100	3800	EPOXY

Top-more than 300 mm of concrete under a horizontal bar

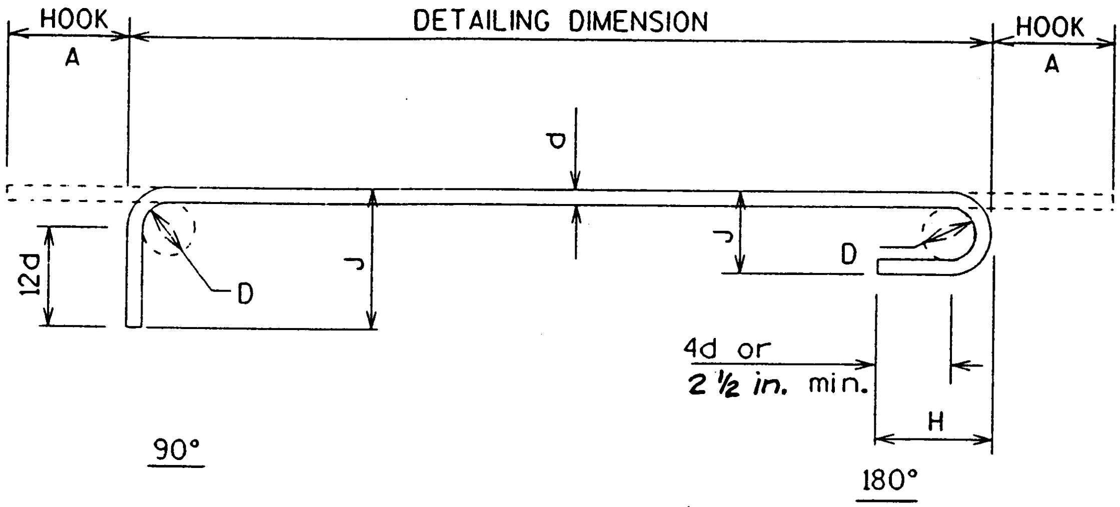
CLASS A - Bar stress is 50% or less, Bars spliced are 75% or less.

CLASS B - Bar stress is greater than 50%, Bars spliced are 50% or less or Bar stress is 50% or less, Bars spliced are greater than 75%.

CLASS C - Bar stress is greater than 50%, Bars spliced are greater than 50%

TABLE 9.2 TENSION LAP SPLICE LENGTH OR DEVELOPMENT LENGTH

APPLIES TO LFD OR LRFD



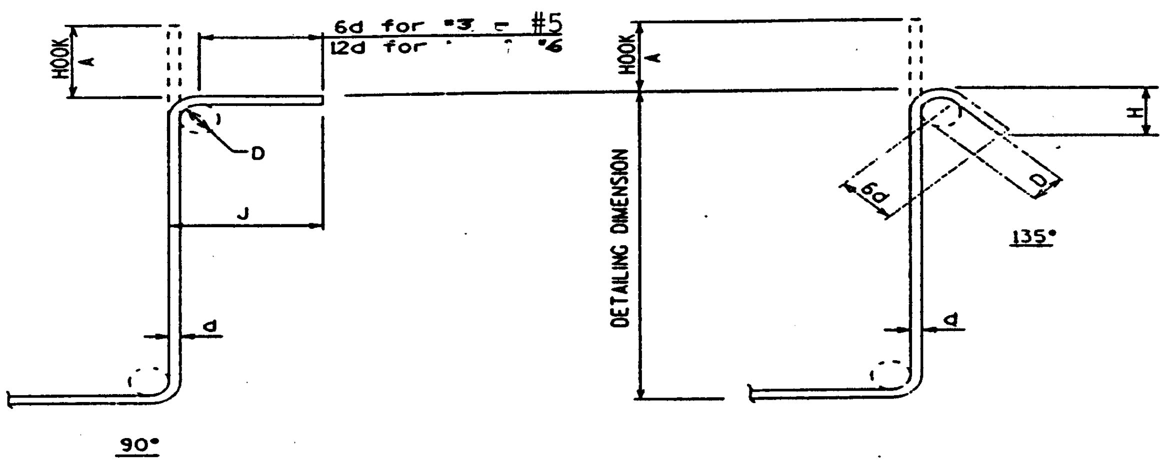
MINIMUM BEND DIAMETER

D = 6d FOR NO. 3 THRU NO. 8
D = 8d FOR NO. 9, 10, and 11

BAR SIZE	MINIMUM HOOK, ALL GRADES					
	90° HOOKS			180° HOOKS		
	HOOK A	J	*J MINUS A	HOOK A	J	APPROX. H
4	7	8	1	6	4	4 ½
5	8 1/2	10	1 1/2	7	5	5
6	10	1-0	2	8	6	6
7	1-0	1-2	2	10	7	7
8	1-1 1/2	1-4	2 1/2	11	8	8
9	1-4	1-7	3	1-3	11 1/4	10 ¼
10	1-6	1-9 1/2	3 1/2	1-5	1-0 3/4	11 ½
11	1-8	2-0	4	1-7	1-2 1/4	1-0 ¾

*** “J” MINUS “A” - DEDUCT FOR ONE BEND**

TABLE 9.5 HOOKS AND BENDS FOR STANDARD BARS-LFD & LRFD



MINIMUM BEND DIAMETER

D = 4d FOR NO. 5 AND SMALLER

D = 6d FOR NO. 6 THRU NO. 8

BAR SIZE	D	90° HOOK		135° HOOK	
		HOOK A	APPROX J	HOOK A	H
3	1 1/2	3	3 1/2	3 1/2	2 ½
4	2	3 1/2	4 1/2	4 1/2	3
5	2 1/2	4 1/2	5 1/2	6	3 ½
6	4 1/2	10 1/2	12	8	4 ½

TABLE 9.6 HOOKS AND BENDS FOR STIRRUPS AND TIES-LFD & LRFD

BILL OF BARS

NOTE: THE FIRST DIGIT OF THE BAR MARK SIGNIFIES THE BAR SIZE

BAR MARK	COAT	NO. REQ'D.	LENGTH	BENT	BAR SERIES	LOCATION
S501		10	4-2		Δ	SLAB - TRANS.
S502		20	6-2		Δ	SLAB - TRANS.
S503	X	19	42-8			SLAB - LONG.

Δ LENGTH SHOWN FOR BAR IS AN AVERAGE LENGTH AND SHOULD ONLY BE USED FOR BAR WEIGHT CALCULATIONS. SEE BAR SERIES TABLE FOR ACTUAL LENGTHS.

TABLE 9.7 BILL OF BARS

BAR SERIES TABLE

MARK	**NO. REQ'D.**	**LENGTH**
S501	1 SERIES OF 10	2-1 TO 6-3
S502	2 SERIES OF 10	3-2 TO 9-5

BUNDLE AND TAG EACH SERIES SEPARATELY

TABLE 9.8 BAR SERIES

BAR AREAS PER NUMBER OF BARS (Sq. In.)

SIZE NO.	WEIGHT LBS/FT	DIA. IN.	AREA	NUMBER OF BARS								
				2	3	4	5	6	7	8	9	10
4	0.668	.500	.1964	0.40	0.60	0.80	1.00	1.20	1.40	1.60	1.80	2.00
5	1.043	.625	.3068	0.62	0.93	1.24	1.55	1.86	2.17	2.48	2.79	3.10
6	1.502	.750	.4418	0.88	1.32	1.76	2.20	2.64	3.08	3.52	3.96	4.40
7	2.044	.875	.6013	1.20	1.80	2.40	3.00	3.60	4.20	4.80	5.40	6.00
8	2.670	1.00	.7854	1.58	2.37	3.16	3.95	4.74	5.53	6.32	7.11	7.90
9	3.400	1.128	1.0000	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00	10.00
10	4.303	1.269	1.2656	2.54	3.81	5.08	6.35	7.62	8.89	10.16	11.43	12.70
11	5.313	1.410	1.5625	3.12	4.68	6.24	7.80	9.36	10.92	12.48	14.04	15.60

AREA OF BARS PER FOOT (Sq. In.)

SIZE NO.	6”	6 ½ “	7”	7 ½”	8”	8 ½”	9”	10”	11”	12”
4	.39	.36	.34	.31	.29	.28	.26	.24	.21	.20
5	.61	.57	.53	.49	.46	.43	.41	.37	.33	.31
6	.88	.82	.76	.71	.66	.62	.59	.53	.48	.44
7	1.20	1.11	1.03	.96	.90	.85	.80	.72	.66	.60
8	1.57	1.45	1.35	1.26	1.18	1.11	1.05	.94	.86	.79
9	2.00	1.85	1.71	1.60	1.50	1.41	1.33	1.20	1.09	1.00
10	2.53	2.34	2.17	2.02	1.90	1.79	1.69	1.52	1.38	1.27
11	3.12	2.88	2.68	2.50	2.34	2.21	2.08	1.87	1.70	1.56

TABLE 9.9